

APPENDIX L

SEATTLE DISTRICT'S

TDG REPORT

Introduction

The Seattle District (CENWS) monitored total dissolved gas (TDG) at Chief Joseph Dam and Libby Dam in the Columbia River Basin in water year 2002. Monitoring at Chief Joseph Dam consisted of measuring TDG at a forebay and tailwater station during the 2002 spill season. Each station collects and transmits hourly data via the Geostationary Operational Environmental Satellite (GOES) system every 4 hours to the Corps of Engineers Northwestern Division (CENWD) in Portland, Oregon. The data is stored in the Columbia River Operational Hydromet Management System (CROHMS) database. Monitoring at Libby Dam consisted of measuring TDG at 31 locations downstream of the dam during voluntary and involuntary spill that occurred from June 24 to July 7, 2002. TDG data collected at Libby Dam were not transmitted via the GOES system and were not stored in the CROHMS database.

The following sections briefly describe TDG conditions that existed at Chief Joseph Dam and Libby Dam during the 2002 water year.

Chief Joseph Dam

Total dissolved gas (TDG) sensors are permanently installed in the dam forebay and tailwater. The forebay station is located in Lake Rufus Woods (the reservoir upstream of Chief Joseph Dam) near the left bank by the powerhouse, approximately 51 miles downstream of Grand Coulee Dam. The tailwater station is located close to the right bank, $\frac{3}{4}$ -mile downstream from the dam. Dissolved gas studies conducted in 1999 determined that the tailwater station sensor measures TDG levels in the spilled water before it mixes with powerhouse flows.

The Chief Joseph forebay station had 53 days exceeding the 12 hour average 115 % TDG concentration, as shown in Table 3 of the TDG annual report. As shown in the TDG graphs in Appendix G, these exceedances began on June 14 and lasted through August 5, 2002. Because little degassing occurs during transport through Lake Rufus Woods, TDG levels measured at the Chief Joseph forebay station are largely a function of TDG levels released from Grand Coulee Dam.

The Chief Joseph tailwater station had 11 days exceeding the 12-hour average 120 % TDG concentration as shown in Table 3 of the TDG annual report. As shown in the TDG graphs in Appendix G, the exceedances occurred between June 2 and July 4, 2002. Except for the exceedance on June 2, all other exceedances were due to involuntary spill resulting from a combination of high river flows and the derating of the DC and AC intertie lines in early June, and flood control operations in early July. The June 2 TDG exceedance was due to Chief Joseph spilling approximately 16 kcfs from only 8 bays (2 kcfs per bay), instead of spreading the spill out over 16 bays (1 kcfs per bay). The higher spill volume per bay resulted in abnormally high TDG levels for such a small total spill volume.

Libby Dam

The Seattle District conducted a total dissolved gas (TDG) monitoring study at Libby Dam during June and July 2002. The purpose of the study was to define and quantify processes that

contribute to dissolved gas transfer during spill releases at Libby Dam. The study focused on resolving questions regarding accurate source and sink descriptions of mass conservation of dissolved gases in the Kootenai River below the dam. TDG time history information across fixed station sampling transects as related to specific project operations were of particular interest. The data was analyzed to provide estimates of the gas transfer throughout the tailwater area, guidance on the relative importance of gas exchange processes within the stilling basin and in the downstream tailrace channel, and to determine the downstream changes in TDG saturation in the Kootenai River.

The specific objectives of the field investigations were as follows:

- Describe dissolved gas exchange processes (exchange, mixing, transport) in the Libby Dam tailwater for various spillway/powerhouse operational scenarios
- Describe resulting TDG pressures downstream to the Kootenai Falls reach associated with the test spillway/powerhouse operational scenarios
- Provide recommendations for future WQ monitoring as needed
- Provide recommendations for minimizing TDG resulting from Libby Dam project operations

Study Approach

The original study design called for spillway flows at Libby Dam to be increased incrementally by 1 kcfs up to a maximum of 10 kcfs for a three-hour duration over a three-day testing period between June 24 and June 26, 2002. However, high project inflows coupled with limited lake storage resulted in involuntary spill superceding the scheduled test spill. The involuntary spill began on June 25 and lasted 13 days until July 7.

The field study required the deployment of an array of automated remote logging water quality instruments that are capable of sampling the complete time histories of TDG pressures in the river/reservoir system. The data collected by the water quality instrumentation during the study included the date, time, instrument depth, water temperature, TDG pressure, dissolved oxygen concentration, and internal battery voltage. The geographic location of each sampling station was also recorded. The water quality parameter of primary interest was TDG pressure. These data were collected at fifteen-minute intervals during the deployment period. Manual sampling was used where and when necessary to supplement the automated approach.

In order to maintain TDG levels within a 120 percent saturation margin of safety, real time measurements of TDG were taken at a checkpoint located approximately one mile downstream from the dam. The original spill events were scheduled to increase in discharge subject to the finding from biological testing of caged and free ranging fish and the TDG level at a point of compliance. The water quality criterion triggering the reevaluation of test events was defined by a three-hour average of TDG saturation exceeding 120 percent at the compliance station. Also, spill was to be suspended for any test where TDG reading exceeds an average of 125 percent saturation for one hour at the checkpoint station. However, once involuntary spill superceded the original study, water quality limitations were no longer applicable.

Study Design

An array of 31 TDG instruments was deployed in the Kootenai River to measure the TDG pressures from Libby Dam to the Canadian border. The TDG pressure above and below Libby Dam was sampled from June 23 through July 9 at 15-minute intervals. The water temperature, instrument depth, dissolved oxygen concentration, and instrument voltages were also measured at many sampling stations during the study period. The general location of sampling transects are shown in Figure L-1 and a description of these station locations are listed in Table L-1. The general philosophy behind the sampling array was to determine the change in TDG saturation in the Kootenai River caused by Libby Dam operations.

The involuntary spill resulted in a range of spill events with a longer duration than scheduled in the original spill test. Spillway flows less than 4 kcfs were limited because of the volume of involuntary spill required for pool management. A series of events were identified during the spill window to correspond with fixed operations for a duration of 1 hour or longer. A total of 23 spill events were identified using this criterion. The shortest events lasted only 45 minutes. The longest event occurred during July 5th and 6th with a duration of 20.75 hours. The TDG exchange in the Kootenai River below Libby Dam was determined for each event and the TDG response evaluated as a function of project operations.

Results

Temperature and TDG pressure were non-uniform in the forebay of Libby Dam. Thermal stratification occurred during the study and resulted in a thermally induced TDG pressure gain in the surface layer of the reservoir. Consequently, near surface TDG was elevated, approaching 115 percent saturation. However, powerhouse releases during the study were generally well below the warmer surface water layer and powerhouse TDG concentrations ranged from 102 to 104 percent. The TDG saturation of spillway flows in the stilling basin showed a marked increase over forebay and powerhouse flows. The initiation of spill (0 – 4 kcfs) resulted in an abrupt increase in stilling basin TDG saturation (104 – 130 percent). A mild increase (130 – 134 percent) in TDG saturation was noted for greater spill volumes (4 – 15 kcfs).

As for TDG Exchange in the Kootenai River, the mixing zone develops quickly between spillway and powerhouse flows as water exits the stilling basin and is transported downstream. A strong lateral gradient in TDG saturation was evident across the river after about 0.6 miles at the USGS transect (see Table 1), with elevated TDG saturations measured on the left bank and TDG saturations similar to powerhouse flows measured on the right bank. The TDG saturation was well mixed laterally after about 6 miles at the Haul Bridge transect (see Table 1) and at sampling stations beyond this point.

During the study, a decline in TDG saturation was typically observed in the Kootenai River between the dam and Kootenai Falls. For example, maximum TDG saturations measured in the river were 130+ percent at the USGS transect (about 0.6 miles downstream of the dam), 120+ percent at the Highway 37 Bridge transect (about 1.6 miles downstream of the dam), and a maximum of 117 percent below the Haul Bridge transect (about 6.3 miles downstream of the dam). The reduction in TDG pressure is due to dilution from tributary inflows and off-gassing at the air/water interface. The degassing process is likely accelerated in rapids where standing and breaking waves increase the surface area for TDG exchange between the water and air.

TDG data collected above and below Kootenai Falls (about 24 miles downstream of the dam) indicate that Kootenai River average TDG saturations were increased up to 116-120 percent saturation from the TDG exchange processes associated with the water passage through Kootenai River Falls during the sampling period. In contrast, spill operations at Libby Dam resulted in the average TDG saturation in the Kootenai River as measured at the USGS transect ranging from 103 to 119 percent saturation during the same period. The gross average river TDG below the falls for the entire test period was 118 percent, 4 percent higher than the 114 percent TDG saturation calculated for the USGS sampling transect. These data indicate that Kootenai Falls generated higher average TDG pressures in the Kootenai River than was generated by the involuntary spillway operations of Libby Dam during June and July of 2002.

Conclusions

Based on preliminary TDG saturation data the following conclusions can be made:

- Temperature and TDG saturation are non-uniform in the forebay.
- Powerhouse releases generally do not change TDG saturations.
- TDG saturation in spill increased as an exponential function of spill discharge.
- Lateral gradients in TDG saturations diminish with increasing distance downstream and are nearly well mixed below the Haul Bridge (about 6.3 miles downstream).
- Riverine processes influence TDG saturations in the Kootenai River.
- Kootenai Falls elevated average TDG saturations in the river to levels greater than the involuntary spillway operations of Libby Dam.

Table L-1. Summary of Dissolved Gas Sampling Stations

Station Description	Distance From Libby Dam (Miles)	River Miles (Miles)	Station Label	Number of Sampling Stations	Location Comments
Forebay	-0.1	222	FB	1	Deployed from log boom, fixed depth
Libby Dam	0	221.9	DTD	1	Draft Tube Deck at Turbine 4
Stilling Basin	0	221.9	SB	1	Temporary Station 1st Event
Below Stilling Basin	0.1	221.8	SPW	2	250 ft Downstream of Stilling Basin
Thompson Bridge	0.4	221.5	TMPBR	4	Left Bank, Quarter Points
USGS Station	0.6	221.3	USGS	5	Left, Right, Three Intermediate Points
Highway 37 Bridge	1.6	220.3	FISHER	3	Bridge Deployed, Left, Center, Right
Haul Bridge	6.3	215.6	HAUL	2	Left and Right Bank
Upstream Libby, MT	12.6	209.3	UPLIBBY	2	Left and Right Bank
Downstream Libby, MT	18.7	203.2	DSLIBBY	2	Left and Right Bank
Upstream Kootenai Falls	23.9	198	UPFALLS	2	Left and Right Bank
Downstream Kootenai Falls	25.7	196.2	DSFALLS	1	Left Bank
Kootenai River near Troy, MT	32	189.9	TROY	1	Right Bank
Kootenai River near Porthill, ID	116	105.9	PORTHILL	1	Right Bank

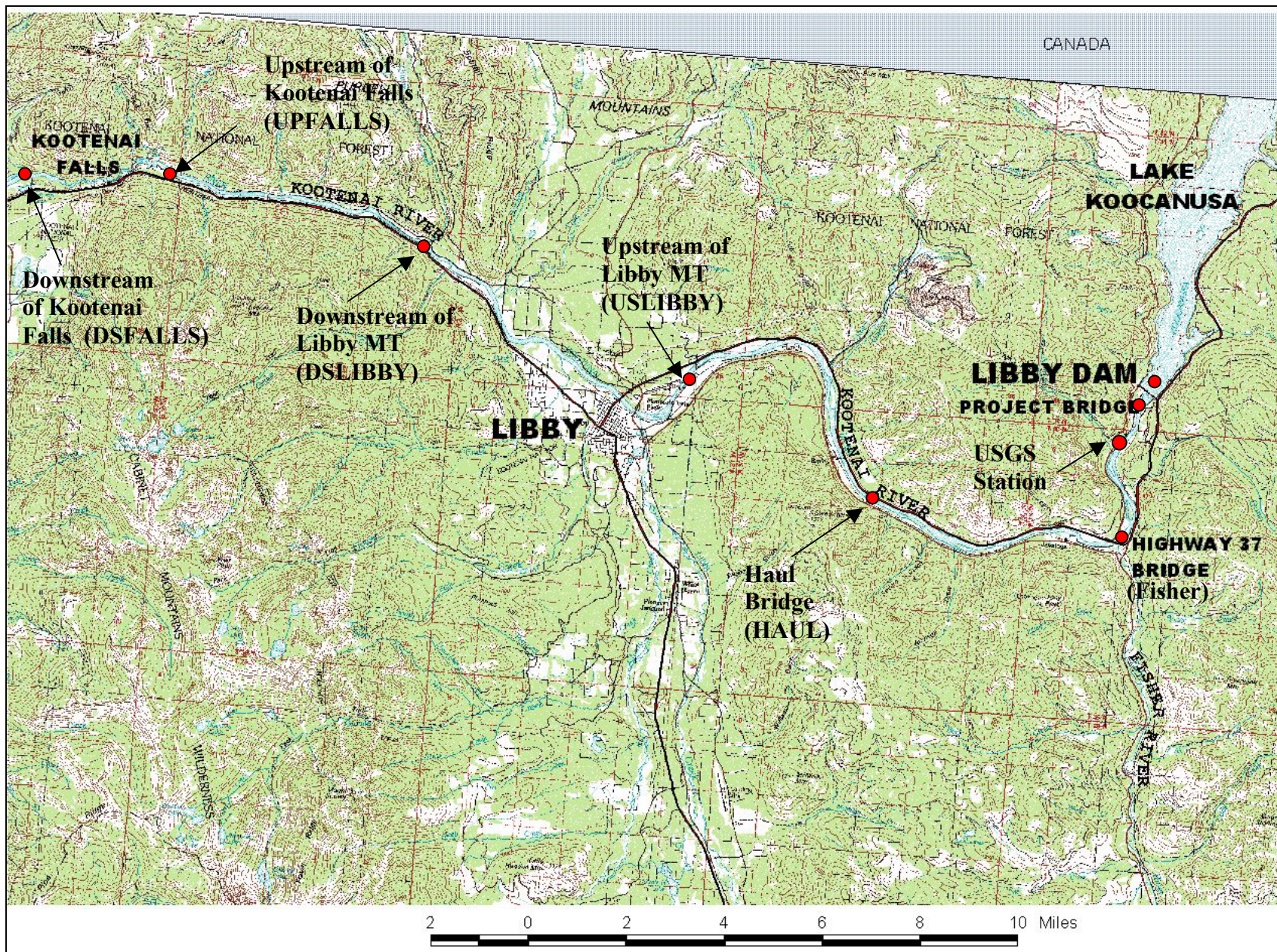


Figure L-1. Total Dissolved Gas Sampling Transects in the Kootenai River near Libby Dam.